

may be remarked here, as has been done by the previous writers, that the establishment of the diplanetism of *Achlya* brings it much closer to *Saprolegnia*. Indeed the structural differences between them become reduced to a single one; namely, that while in *Achlya* the sporangia formed from a filament arise after the first one by lateral outgrowth below the basal walls of the previous ones, in *Saprolegnia* they usually arise inside of the preceding ones by the upward growth of the successive basal walls. But I have seen, in an undetermined species of *Saprolegnia*, the formation of secondary sporangia after the *Achlya* type on a few filaments. There remain to be noticed two physiological differences so closely connected as to constitute, perhaps, a single phenomenon. The first swarming period in *Achlya* is reduced to its lowest terms, and at its close the zoöspores become aggregated into a hollow sphere at the mouth of the sporangium, in response to an apparent mutual attraction which Hartog¹ has termed adelphotaxy. Is this mutual attraction the cause of the shortness of the first swarming period?

Amherst, Mass.

A contribution to the life history of *Hydrastis Canadensis*.

HOMER BOWERS.

(WITH PLATE VIII.)

About ten years ago while engaged in the cultivation of various indigenous plants and the study of their germination and growth some deviations were observed in the behavior of *Hydrastis Canadensis* so at variance with the accepted view of the life history, that a minute study of all its peculiarities was begun and from that time to the present it has been followed with the view of bringing the facts to the attention of botanists.

My attention was first drawn to the plant specially, on discovering a stage in its growth concerning which no record exists. Afterwards when investigation disclosed that this unknown stage embraces a feature anomalous in the growth of plants, a great incentive for further research was added. This at length brought to light two other important facts

¹Annals of Botany, vol. ii, no. vi, p. 216.

that seem never to have been noticed, besides several minor points that are unrecorded, together with some slight errors of observation or description. The proper statement of these facts necessitates an account of the life history.

SYNOPSIS OF THE LIFE HISTORY.—*Hydrastis Canadensis* is a perennial herb found growing in patches in rich open hilly woods, and on the slopes along the wooded bluffs and secondary banks of streams. The seed naturally sown after the ripening of the fruit in July or August, does not germinate until the following spring, about the last week in April, or the first in May. The plantlet consists of a pair of orbicular cotyledons on long spreading petioles, joined to a slender radicle, and makes no further advance in growth the first year of its life, other than the development of the cotyledons, together with the attached radicle, surmounted by a large bud. The seed-leaves alone do duty for foliage during the whole growing period of this stage of its existence.¹

The second year it sends up a single rounded, palmately-lobed leaf on a footstalk articulated at the root. This stage often persists through the third year; the plant then sends up a larger radical leaf, with perhaps one or more smaller ones in addition.

The third or fourth year the stem arises 15 to 30 or more cm. high, having two alternate leaves, with two-ranked arrangement, the lower larger and petioled, the upper sessile at the junction of the peduncle of the flower with the stem of the plant.

It has thus three stages of growth, being acaulescent for two or more years, and bearing fruit the third or fourth year. The bud-scales found at the base of the stem are two-ranked, conduplicate, and equitant. Under certain conditions it propagates itself by adventitious buds from fibrous roots. There are also evident stipules.

DETAILED DESCRIPTION.—*First stage, duration one year.*—The cotyledons on first appearing are bright emerald green, glossy, oval, about 5 mm. broad and 6 mm. long. The petioles are long and somewhat thickened; the radicle long and slender. The cotyledons attain their full size in about three

¹ Rarely, in a very vigorous seedling, a small radical leaf on a short footstalk will be sent up late in June or early in July, and also in a few instances where seedlings have been transplanted at an early stage to a more favorable location, a small radical leaf has been observed to spring up.

weeks, when they measure 8 to 12 mm. in diameter. In general outline they are now orbicular, and slightly emarginate, with three basal nerves, well defined on the under surface, and of a dull green color. The petioles are now long, slender, slightly pubescent, somewhat divergent, and joined to the radicle 6 to 12 mm. below the surface.

In August or September, after the first stage of growth has been completed, the plant consists of the following parts: A few fibrous roots at irregular intervals along a thickened and tapering radicle, from the summit of which a small yellow bud arises about 4 mm. in height; and the two foliaceous cotyledons, showing evidence of maturity and decline, with their petioles inserted at its base.

Second stage, duration one or two years.—The rootstock is small, erect, somewhat conical, and continuous with what constituted the radicle of the first year, which gives off several fibrous roots. There is no stem as yet, and the single leaf is round-cordate, sometimes partially peltate, palmately five-lobed, doubly serrate, with a cup-like depression at base, sits horizontally on a footstalk 5 to 15 cm. long that is articulated on the rootstalk, and has evident stipules.

Third stage, duration indefinite.—The rhizome is knotty, variously contorted, erect, with many long fibrous roots of a bright orange color. The stem arises from a terminal bud 15 to 30 cm. or more high, 4 to 6 mm. in diameter, erect, round, more or less pubescent, yellow below the surface, becoming purplish from the point of exposure to light a short distance upward. Three and sometimes four bud-scales embrace the base of the stem, the inner much the largest. They are conduplicate, equitant, strongly keeled, hooded, mucronate, 10 to 15-nerved, the lateral margins membranaceous. They arise from nodes 4 to 6 mm. apart, and are yellow, becoming purplish if exposed at the surface, and are homologous with stipules. The leaves are now two, rarely three, alternate, with two-ranked arrangement, and plicate vernation. The lower leaf is the larger, 15 to 30 cm. in lateral diameter when mature, with five acute ovate-lanceolate lobes well-defined by deep incisions. The sinuses are always well rounded at the bottom, never acute, though often narrow; the lobes mostly overlap each other and two lateral ones bear one or more minor lobes on their lower borders. The general outline is between reniform and cordate; the basal sinus is very narrow,

the margins often overlap to some extent and occasionally unite for a short distance, thus making the leaf partially peltate.

In all cases a cup-like depression exists at the insertion of the leaf-blade. The petiole is 2.5 to 7.5 cm. long, roundish, thick, swelling at the base and amplexicaul, with small tubercular stipules visible at an early age. The petiole and stem both diverge at their point of junction, giving the appearance of a bifurcate stem. The upper leaf is smaller, sessile at the junction of the peduncle of the flower with the stem, and partly clasping. The absence of the leaf-stalk in the smaller, combined with the angle of insertion of both blades, causes the leaves to occupy the same horizontal plane. The third leaf, when present, is much smaller, often distorted, always sessile on the peduncle, and possibly should be regarded as a bract. The flower is white, with a diameter of 12 to 18 mm., solitary, erect, terminal, on a peduncle 12 to 25 mm. long, with 3 or 4 orbicular, concave, green or purplish, caducous sepals, and no petals.

The stamens are 50 to 75, spreading, curving outward and upward, the pure white filaments gradually dilated from the base outward and somewhat contracted near the summit. The anthers are pale straw-color, adnate, with lateral longitudinal dehiscence. The 10 to 20 or more pistils are in a head, with white flat broadly two-lipped stigmas, the lips thin, rounded, and wavy-margined. The style is straw-colored, short and thick, being simply a contraction of the upper part of the ovary. The olive-green oval ovary is somewhat gibbous, sparingly pubescent, sulcate along the whole ventral aspect and the upper third of the dorsal, 1-celled and 2-ovuled. The red fruit resembles a raspberry and ripens in July or August. It consists of an aggregation of fleshy carpels, forming a globular head, each carpel bearing at summit the persistent style which is strongly inclined toward its dorsal aspect. The one or two seeds are small, about 2 by 3 mm. ovoid, black, hard and polished, anatropous, pendulous, with ventral raphe, fleshy albumen, and minute embryo.

GENERAL OBSERVATIONS.—The anomalous behavior of this plant in its first stage of growth has escaped observation, partly, I suppose, on account of its retiring habits. It always grows in patches in secluded and shady spots, where the earth is carpeted with decaying leaves; often beside rotting logs, where

the roots are mulched by the decaying wood. The seed-leaves being small and often lying almost flat on the surface, would be observed only by chance; even then there would be nothing in their appearance to connect them with the plant under consideration, unless removed from the earth, when the root by its bright yellow color might indicate the relationship to *Hydrastis*.

In germination the cotyledons often arise from the earth separated by an interval of 2mm. or more and sometimes one cotyledon will show itself a day or so before the other one appears. If from any cause the cotyledons are destroyed early in summer the lemon-tinted bud does not grow until the following spring. Usually four different kinds of buds are found on an old plant, viz. large winter buds of two kinds, terminal and axillary; small latent buds, with scales but slightly developed; and adventitious buds that are formed on root fibers under certain conditions.

The winter buds of *Hydrastis* are large and deserving of special study, not only as illustrating the perfect protection that is so often provided for the tender parts during hibernation, but also as furnishing an excellent example in the morphology of leaves, the scales being homologous with stipules. The terminal bud is the largest, and develops the fruiting stem. The axillary bud produces a radical leaf; or, as often occurs, remains dormant for a time. The arrangement of the scales of a terminal bud at the close of the growing season, when the plant has fully completed the preparation for its period of rest, is such that but one, the outer, is truly equitant, the others, each in turn, completely overlapping and enfolding by their hooded and membranaceous expansions the inner till the young shoot itself is enshrouded by the last one.

On removing the scales at this period the young shoot is found to be large; the plicate foldings of the leaves are easily discovered, but the flower-bud is larger than all the rest, the stem being merely a conical eminence upon which the other parts sit. Yet the stipulate amplexicaul base of the petiole is visible, joined to the leaf, seemingly without the intervention of a leafstalk. The sessile leaf is very small indeed, entirely overshadowed by the comparatively enormous flower-bud whose sepals can easily be counted, and the stamens plainly observed.

Stipuliform appendages are ~~not~~ a feature of the order *Ranun-*

culaceæ, but *Hydrastis* has evident stipules, to be seen in the small tubercles, or points, projecting backward and upward from the amplexicaul petiole of the lower leaf of a fertile stem; and more plainly still at the base of the footstalk of a radical leaf, where they will be found, in early summer, incurved or overlapping each other and always enshrouded by the accompanying bud-scale. Later, when growth has ceased and the old bud-scales have decayed, there will be found, emerging from the overlapping stipules of a radical leaf, an abortive leaf on a short and rudimentary petiole, with a fully developed stipulate base, which enwraps another smaller one, and so on till the full complement necessary to the formation of a hibernaculum is present. Then, when the old radical leaf has served its time and is overtaken by decay there will be seen, for a short time, tipping the outer scales of the hibernaculum which sprung from its axil, instead of a mucronation, the depauperate leaf raised on a short and tapering footstalk but a few millimeters in height. Sometimes the depauperate leaf appears surmounting the inner scales of a terminal, or the outer scales of an axillary bud, as a digitate or merely fimbriate attachment without the intervention of a foot stalk. This soon perishes, and nothing will be found, after the bud-scale has expanded in the spring, but the blackened mucro, the remains of the footstalk of a depauperate radical leaf, thus plainly demonstrating that the winter bud-scales of *Hydrastis* are the homologues of stipules.

The development of a radical leaf without an offshoot, or caudex, from a bud in the axil of the lower bud-scale of a fertile stem of the same season's growth often occurs. The planes of insertion of the scales of a new bud are always at right-angles to the plane of the one from whose axil it sprung. Buds are formed in increasing numbers as each year passes, until as many as 20, or, even to 60 fertile stems may be found arising from one rhizome of from six to ten years age, together with a greatly varying number of sterile stems, or radical leaves, ranging from none at all in some cases, to perhaps twenty in others. Among almost every cluster from an old rootstock there will be found one or more stems bearing three leaves. After the annual decay of the stem there is left a cup-like depression at the summit of the caudex.

The persistence of these depressions, each for a few seasons, has given the plant one of its common names "golden

seal." The rootstock is not horizontal, as represented in the drawings of all who have described the plant previously, and if ever found so it is an accident of growth, as I shall proceed to show. Development of rhizome begins with the second year, by the gradual thickening of the head of the primary fibrous root, or radicle. It is difficult to determine at this stage just where the rhizome ends and the root begins. The hibernacula are produced, after the second year, from short offshoots which spring from the axils of previous bud-scales, the offshoots being of such length only as to permit the bud to assume the erect position. The contortion or contraction produced in the rhizome by the decay of some of the offshoots each year is almost always in such manner as to cause the hibernacula to assume a more erect position, one in fact almost continuous with the older part of the rootstock. Thus a perpendicular axis is generally maintained. From this habit of growth an old rhizome is a knotty subdivided mass and presents no regularity of outline. The young rhizome, and the offshoots of the older ones, are marked by slight annular ridges, the sites of former bud-scales. It seems to be a law of development with this plant, that two or more years are required for the perfecting of a terminal bud and its supporting caudex. An old rootstock is abundantly supplied with fibrous roots. These, from their manner of growth and other characteristics, are found to be of two kinds, unequally apportioned. Those most numerous incline downward in their growth and have a length varying from 10 to 20 cm. the others are few in number, and larger, each measuring 20 to 50 cm. or more in length, with a diameter of 1 to 1.5 mm. and growing in a horizontal direction at a depth of 2.5 to 5 cm.

These large fibers under certain conditions sparingly produce adventitious buds, from each of which one or more small radical leaves arise on footstalks. These leaves are identical with the foliage of the second stage of growth from the seed. Three of these buds have been observed on a single large fiber at intervals of 7.5 cm. or more. They seemed to be formed only on those fibers that have been severed from the rootstock without greatly disturbing their distal extremities. Adventitious buds may occur upon the large fibers while yet attached to the rhizome, but if such is the case I have never yet observed it, the budding fiber always being found detached from the plant, with the proximal extremity blackened for a short

distance by incipient decay. Young plants have not been observed to produce budding roots. The leaves have five lobes. Many books give seven, but all over five are as a rule minor lobes whose ribs spring, posteriorly, from the two inferior basal veins. The veins are very prominent on the lower surface and there is a considerable linear depression on the upper surface, in their track. This gives the leaf at the time of flowering, when it is but slightly developed, a very rugose appearance, which persists for some time. The plant puts forth very early, and before the forest is fully clothed in leaves it has attained almost its full development in all points save the expansion and ripening of the fruit, and the maturing of its underground structures. This energy for the first few days is mostly expended in the growth of the stem, which arches over and bends itself as it is extended from the caudex, bursting asunder the bud-scales, which have begun to enlarge rapidly, the inner one especially developing beyond the others. The stem, thus bent, emerges from the earth often 5 cm. or more before the top is dragged forth. Sometimes it happens, when the ground is hard and dry, that it fails to extricate itself, and therefore perishes. The leaves are but slightly developed when the flower appears, which occurs almost immediately after the stem assumes the erect position. The flower lasts five or six days. In a dry season the plant dies down soon after the ripening of the fruit, and by late September the top has disappeared. Again when the season is more moist it will persist even to the beginning of winter.

The fruit when ripe is readily detached from the stem, and has a shallow depression at its base. It is insipid to the taste, non-poisonous, and is eaten by birds, by which means the seeds are disseminated. From various causes but few of the seeds naturally sown ever germinate, and the extension by adventitious buds forming on the root fibers is very slow, as this mode of propagation does not seem to be as well established with this plant as it is with some others.

It would seem from present indications, that the time when *Hydrastis* will be no longer found in our forests is almost at hand. Possibly its total extinction could never have occurred from the settling and clearing up of the country only, since the natural terraces of many inaccessible ravines, bluffs and mountain sides, where the material best suited for its sustenance had accumulated for centuries, would have been its

impregnable strongholds. But the drafts made upon it in pharmacy to supply the growing demand of the medical profession have set upon it that impecunious class, the "sang" and "puccoon" diggers, who have almost exterminated it in many of those regions where it grew in great abundance.

It may yet be found from the Mississippi river to the Alleghenies, as far north as Canada and to Tennessee on the south, with a limited area of distribution beyond the Mississippi, in Missouri and Arkansas¹. Over most of this territory it is now so thinned out that its collection is not the commercial success it formerly was. The above boundaries very nearly mark the extent of the distribution it had attained on the earth's surface in its most flourishing time.

But, in this region of central Indiana, within the area of its former natural abundance, I have demonstrated by experiments of some years' duration, that it can be successfully grown by giving it as far as possible the surroundings that it had in the pioneer days of the country. It endures close association with but few other herbs, yet the shade afforded by many of the shrubs and forest trees, if not too dense, seems to be a requirement essential to its perfect growth and development. The grasses are its deadly enemies, and ground that is trodden will not support it. Under such conditions it quickly perishes. A single large plant, removed from the woods to a suitable situation, I have observed in several instances to spread so that an area of five or six feet in diameter would be occupied in eight or ten years time, without any artificial aid, save the keeping in subjection of all other encroaching plants.

Individual characteristics are noted, as marking with more or less variation each group or patch of plants, indicating, that though *Hydrastis* is a recluse among plants, and presents some deviations that are remarkable, yet this one feature which it possesses in common with most representatives of the vegetable kingdom, may lead through judicious selection and the careful study of its habits of growth, to the establishment, in time, of new varieties. This possibility the following observations of three district patches, originating from plants obtained from different points, and grown on my grounds, seem to show:

¹ Lloyd's *Drugs and Medicines of North America*, vol. 1, no. 3, pl. IX.

Patch no. 1, short: stems 15 to 20 cm.: peduncle short, 6 to 12 mm.: fruit almost sessile on some; carpels 12 to 18: leaves rugose, much incised resulting in many minor lobes, though but five basal veins: color of stems mostly green, slightly purple at base.

Patch no. 2, medium: stems 25 to 30 cm., purplish from base $\frac{1}{3}$ of height: peduncles 18 to 25 mm.: carpels few: leaves coarsely serrate, minor lobes rare, scarcely pubescent, large, many of them 30 cm. across.

Patch no. 3, tall: stems 30 to 37.5 cm. purplish from base $\frac{2}{3}$ of height: peduncles 35 mm.: carpels 25 to 30: leaves slightly rugose, lateral diameter of lower leaves 25 to 30 cm., minutely pubescent.

New Ross, Indiana.

EXPLANATION OF PLATE VIII.—Fig. 1, seedling 2 or 3 days after germination. Fig. 2, seedling at the end of the first season's growth. Fig. 3, second year from the seed. Fig. 4, *a*, top of flowering plant early in May, stipular eminences plainly shown at base of lower leaf; *b*, flower with most of the stamens removed. Fig. 5, part of stem with fruit, late in July. Fig. 6, stipules; *a*, part of fertile stem with amplexicaul petiole of lower leaf, showing tubercular stipules; *b*, caudex with portion of radical leaf petiole, old bud-scales dissected back and showing stipules at base enveloping the rudimentary hibernaculum, depauperate leaf protruding, as observed in June. Fig. 7, stipules as bud-scales; *a*, bud-scales at base of fertile stem, early in May; *b* and *c*, buds formed in the axil of a radical leaf, as they appear in October or November, with outer scales dissected back; *b*, one of the bud-scales surmounted by a depauperate leaf; *c*, same with merely fimbriate attachment; Fig. 8, horizontal root fiber, with adventitious bud and radical leaf. Fig. 9, rhizome with most of the fibrous roots removed, showing perpendicular character of axis. Fig. 10, series showing transition from floral bract to leaf, as sometimes observed in exceptional cases where third leaves are produced; *a*, part of upper portion of stem showing attachment of sessile leaf, floral bract, and fruit soon after anthesis; *b* and *c*, same with bracts more leaf-like.

Two undescribed species of *Apodanthes*.

B. L. ROBINSON.

(WITH PLATE IX.)

It is now more than twenty-five years since the discovery, in western Arizona, of *Pilostyles Thurberi* Gray, a diminutive parasite which, notwithstanding great disparity in size, is nearly related to the famous *Rafflesia* of India. Although the genus *Pilostyles*, or more correctly, *Apodanthes* § *Pilostyles*, is well represented in South America, the rare *A. Thur-*